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THE ROLE OF THE NON-SECULAR SPIN–SPIN INTERACTIONS IN NUCLEAR RELAXATION

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The role of the connection between the secular part of the spin–spin interactions through the non-secular spin–spin interactions with the Zeeman paramagnetic reservoir in nuclear relaxation is considered. Conditions have been determined under which the Zeeman nuclear energy is transferred to the Zeeman impurity reservoir.

1. Introduction

If the spin–spin relaxation time of the electron spins T_2 is shorter than the spin–lattice relaxation time (SLR) T_1 the nuclear relaxation (NR), as is known, proceeds involving the secular part of the spin–spin interactions or the dipole reservoir (DR) of paramagnetic impurity. When investigating the DR role in the NR the electron Zeeman reservoir Z and the DR are considered to be well isolated from each other [1].

In the book by Goldman [2] it has been theoretically, and on the basis of ample experimental data, shown that during the time of the order of T_2 there takes place a thermal mixing of the Z-reservoir with the energy of the non-secular part of the dipole–dipole interactions (NDDI) of the impurity centres, resulting in a single energy reservoir $Z^* = Z + \mathcal{H}_{d''}$. The hamiltonian of the NDDI

$$\mathcal{H}_{d''} = C + D + E + F$$

$$C = D^* = \sum_{i,j} C_{ij}(S_i^+ S_j^Z + S_i^Z S_j^+),$$

$$E = F^* = \sum_{k,l} E_{kl} S_k^+ S_l^+. \tag{1}$$

In [3] it is shown that owing to the joining of Z and $\mathcal{H}_{d''}$ into a single reservoir there is a sufficiently effective connection between the subsystems Z^* and the DR even in strong fields. As is shown in [4] the consistent application of methods treated in [2] leads to the same results as in [3]. In [4] it is justly pointed out that the existence of the connections between DR and Z^* results in important physical consequences. However, there is an erroneous assertion in [4] that the method [2] is wrong in principle. The method [2] is opposed by the approach to the problem of establishment of the spin temperature whose erroneousness we deem it necessary to demonstrate.

It is easy to see that the correlation

$$\langle(\hbar\omega_0 S^Z + \mathcal{H}_{d''})^2\rangle = \langle\hbar^2(\omega_0 + \omega'')^2 (S^Z)^2\rangle;$$
$$\omega'' = \tfrac{1}{2}\omega_0 \frac{\langle\mathcal{H}_{d''}^2\rangle}{\langle Z^2\rangle}, \qquad \langle\ldots\rangle = \frac{\mathrm{Tr}(\ldots)}{\mathrm{Tr}\,1}, \tag{2}$$

is fulfilled with the precision of up to the second order of H_{loc}/H_0. The value $\hbar\omega''$ corresponds to the amendment of the energy in the second order at the expense of $\mathcal{H}_{d''}$ [5]. From the correlation (2) it does not follow that the formal substitution of the Z^*-reservoir by the $\bar{\mathcal{H}}_Z = \hbar(\omega_0 + \omega'')S^Z$ is correct. However, in [4] such substitution is present from the very beginning. The process of the formation of the $\bar{\mathcal{H}}_Z$-reservoir and the possibility of its utilization when considering dynamic phenomena, is not treated in [4]. The modified secular part of the spin–spin interactions in [4] is written in the form